ELECTRONIC FUNDAMENTALS

EXPERIMENT LESSON 19

TRIODE EXPERIMENTS

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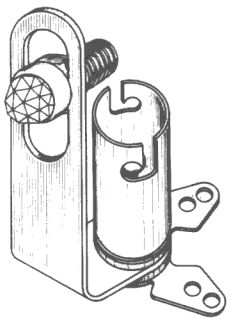
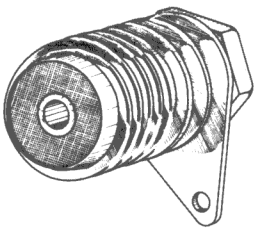


pilot-light socket and jewel assembly



chassis connector

All the parts in Kit 10 are listed below. Check the parts you receive against this list. Make sure you have the correct quantity of every item. If a part is either missing or defective upon arrival, request a replacement from Department R, Home Study School, RCA Institutes, Inc., 350 West 4th Street, New York 14, N.Y. *Your request must include your name and student number, the complete name and description of the part copied from the Item column below, the Quantity missing or defective, and the reason you are asking for a new part.*

KIT 10

BILL OF MATERIALS

Quantity	Item
1	12AU7 electron tube
1	6AT6 electron tube
1	Potentiometer, 5,000-ohms, with switch attached
1	Potentiometer, 500 k-ohms, with switch attached
1	Subchassis for signal generator
1	Front panel for signal generator
2	Chassis connectors
1	Pilot-light socket and jewel assembly

Quantity	Item
1	Resistor, 22 k-ohms, 2-watts
1	Resistor, 470-ohms, 1-watt
1	Resistor, 330-ohms, 1/2-watt
1	Resistor, 3,300-ohms, 1/2-watt
1	Resistor, 8,200-ohms, 1/2-watt
1	Resistor, 33 k-ohms 1/2-watt
1	Resistor, 47 k-ohms, 1/2-watt
2	Capacitor, 0.006-μf, 600 volts d.c.
2	Capacitor, 0.01-μf, 400 volts d.c.
1	Capacitor, 0.02-μf, 400 volts d.c.

If you get a part slightly different from a part described in this list, the substitute part will not interfere electrically or mechanically with your experiments or equipment.

Experiment Lesson 19

OBJECT

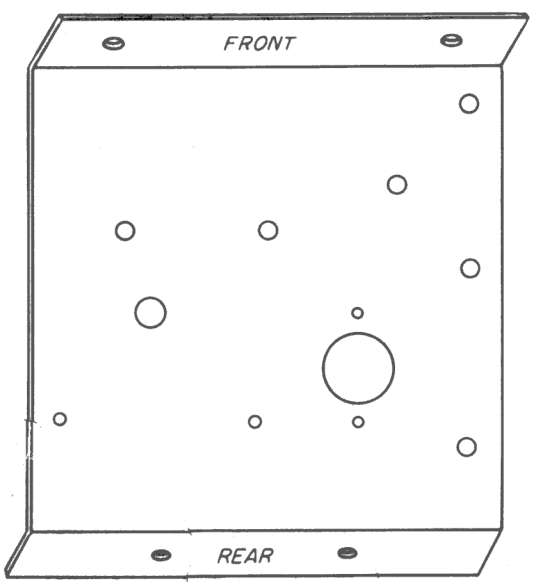
To verify some important characteristics of the triode-type electron tube.

INFORMATION

Triode and multigrid electron tubes are used in many ways in many circuits. You studied the principles of triode and multigrid tubes in Theory Lesson 19. In this Experiment Lesson, you will find what you learned about principles of triode and multigrid tubes is borne out by the experiments you will perform. These experiments will be performed using one-half of a 12AU7 twin-triode tube. Look up the 12AU7 in the tube manual. Note that there are two identical triodes in one tube envelope. In this lesson, you will perform experiments in the left-hand triode, which is made up of a plate (pin 1), a control grid (pin 2), and a cathode (pin 3). The heater is common to both triodes and heats both cathodes. Either 6.3 volts or 12.6 volts may be applied to heat the cathode of the tube.

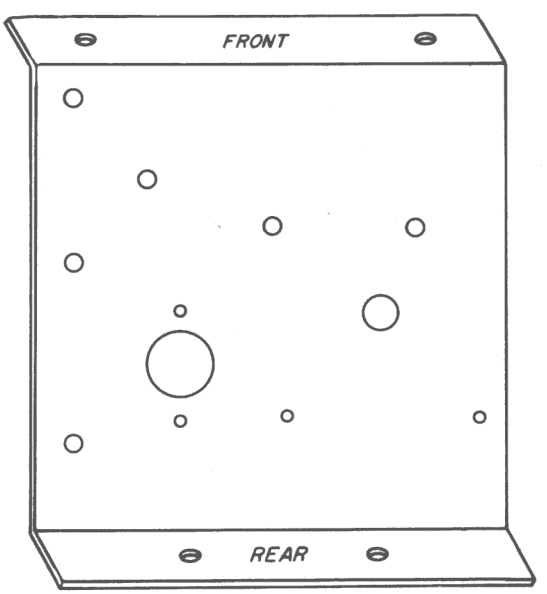
Experiments will be performed on the signal-generator subchassis, in conjunction with the wired power supply of the receiver. When the experiments are completed, you will have also started the construction of your r-f and a-f signal generator.

Figure 19-1 (*a* and *b*) shows the top and bottom views of the signal-generator subchassis before the mounting of any parts. *Carefully* study your subchassis and determine which side is top or bottom. Label the top, bottom, front, and rear of the subchassis with crayon. During this and future experiments involving the signal generator, work with the subchassis in either one of these two positions *with the rear of the subchassis nearest you.* When working on subchassis, use two blocks of wood for support.



top view

(a)



bottom view

(b)

Fig. 19-1

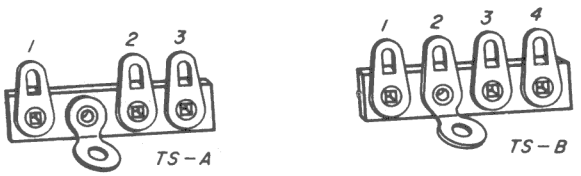


Fig. 19-2

Wiring will be made to terminal strips, such as the ones shown in Fig. 19-2. Terminal strip will be abbreviated as *TS* in these lessons. If more than one terminal strip is used, the letters *TS* will be followed by *A*, *B*, etc. Then lugs on the terminal strips are numbered from left to right, when the terminal strips are viewed with the mounting lugs facing you. Figure 19-2 shows two examples.

EQUIPMENT NEEDED

Radio-receiver chassis with wired, operable power supply

Multimeter

Signal-generator subchassis

A-C power transformer

9-pin tube socket

6-foot power cord with attached male plug

One 4-lug terminal strip

One 3-lug terminal strip

One locking-type grounding lug

12AU7 electron tube

500,000-ohm potentiometer

Four flashlight cells (from Kit 7)

One 1/2-inch rubber grommet

One 3/8-inch rubber grommet

Two #4 lock washers

Two #6 lock washers

Hookup wire

Knob

Hardware

One 22,000-ohm resistor

JOB 19-1

To mount the following components on the signal-generator subchassis: power transformer, 9-pin tube socket, two terminal strips, two rubber grommets, and a ground lug.

Procedure.

Step 1. Insert the 9-pin tube socket in the underside of the hole, with the blank space between pins 1 and 9 facing the rear. Fasten with two 4-36 x 1/4-inch screws, two #4 lockwashers, and two 4-36 nuts.

Step 2. Study the mounting of the transformer in Fig. 19-3 before doing this step. Place the transformer on the subchassis over the mounting holes with the leads facing away from the tube socket. Take a 6-32 x 1/4-inch screw, insert through the left side (as seen from the rear) mounting hole of the transformer. On the underside insert, a 3-lug terminal strip (to be referred to as TS-A), a #6 lock washer and nut, and then tighten. Label the terminal strip on the underside of the chassis for future identification.

Take a 6-32 x 1/4-inch screw, insert it through a locking-type grounding lug, and through the right side mounting hole of the transformer. On the underside, slip a 4-lug terminal strip over the screw, and tighten with a #6 lock washer, and a #6 nut. This 4-lug terminal strip will be referred to as TS-B. Label it on your chassis.

Step 3. Insert a 1/2-inch rubber grommet in the 1/2-inch hole in front of the transformer, and insert a 3/8-inch rubber grommet in the 3/8-inch hole in front of the tube socket.

At this point, check all your mounting work with that shown in Fig. 19-3.

JOB 19-2

To wire the line cord to the transformer primary; the 6-volt secondary heater voltage to the 9-pin tube socket; and miscellaneous wiring.

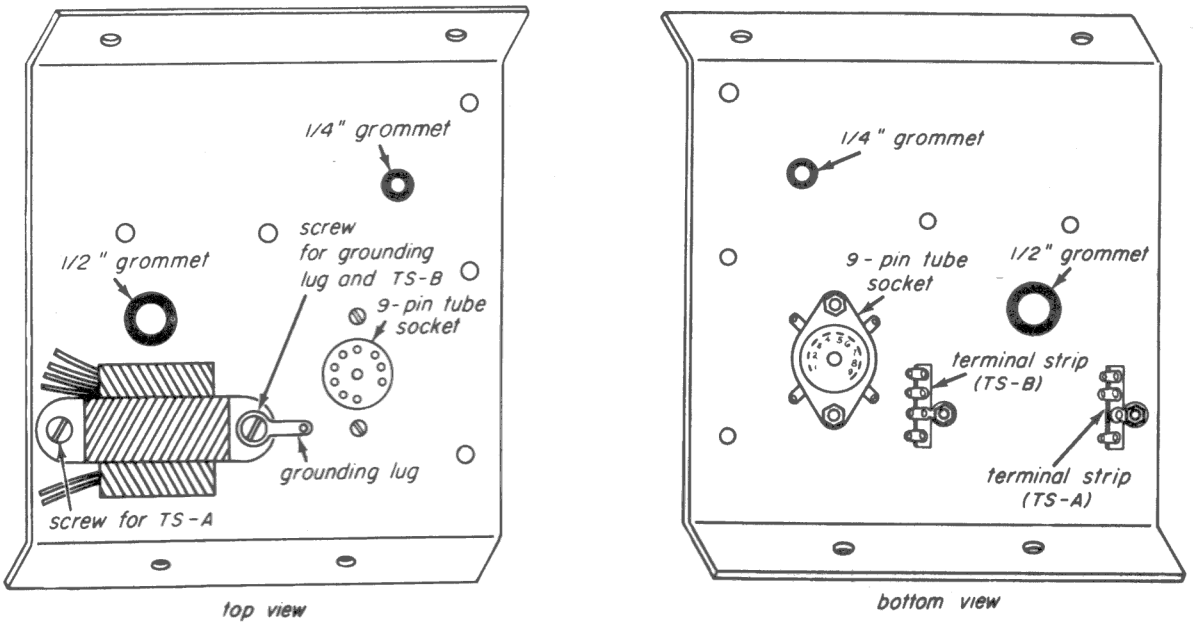


Fig. 19-3

Procedure.

Step 1. Tape the two red (high-voltage secondary) leads of the transformer with plastic electrical tape, as shown in Fig. 19-4*a*.

Step 2. Cut one of the green (6.3-volt) lead 3 inches long, strip 1/4 inch of insulation, dress, and solder it permanently to the grounding lug on top of the chassis, as shown in Fig. 19-4*a*. Leave space in hole of lug for another wire that will be wired in the next Experiment Lesson.

Step 3. Cut the other green lead 5 inches long, strip 1/2 inch of the insulation, run it down through the 1/2-inch grommet to the tube socket, and then solder permanently to pins 4 and 5, as shown in Fig. 19-4*b*. Leave space in lugs 4 and 5 for additional wires.

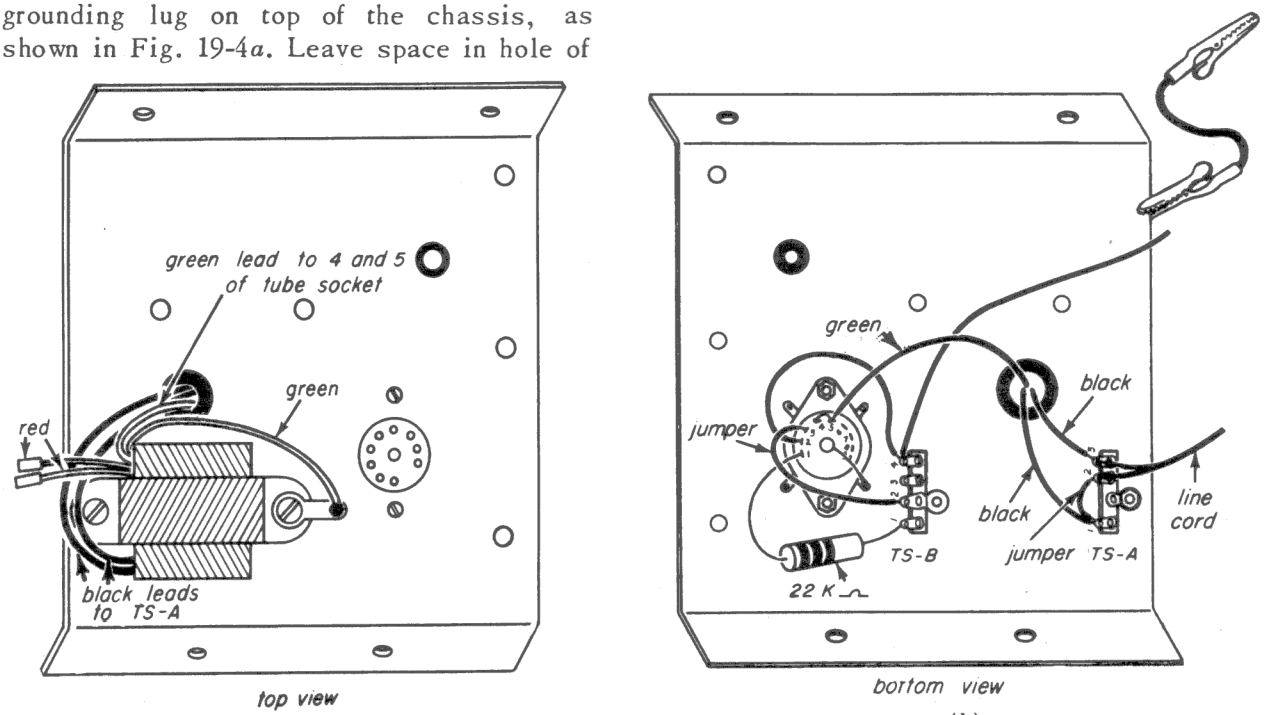


Fig. 19-4

Step 4. With a piece of bare wire, connect and solder permanently the centerpost (and pin 9) of the tube socket to the ground lug near pin 9 on the tube socket.

Step 5. Cut one primary (black) lead 6 inches long, strip 1/4 inch of insulation, pass it down through the large grommet, and connect permanently to lug 1 of TS-A. Do not solder. Cut the other black primary lead 5 inches long, strip 1/4 inch of insulation, pass it down through the large grommet, and connect permanently to lug 3 of TS-A. Do not solder.

Step 6. Connect permanently the line cord to lugs 2 and 3 of TS-A. Do not solder.

Step 7. Connect temporarily a short jumper (about 1-1/4 inch) between lugs 1 and 2 of TS-A. Solder lugs 1, 2, and 3 of TS-A.

Step 8. Connect (do not solder) one 12-inch lead to lug 4 of TS-B.

Step 9. Temporarily solder one end of the 22,000-ohm resistor to pin 1 (plate) of the tube socket and the other end to lug 1 of TS-B.

Step 10. Solder temporarily a short jumper between pin 3 (cathode) of the tube socket and lug 2 of TS-B, and another jumper between pin 2 (control grid) of the tube socket and lug 4 of TS-B.

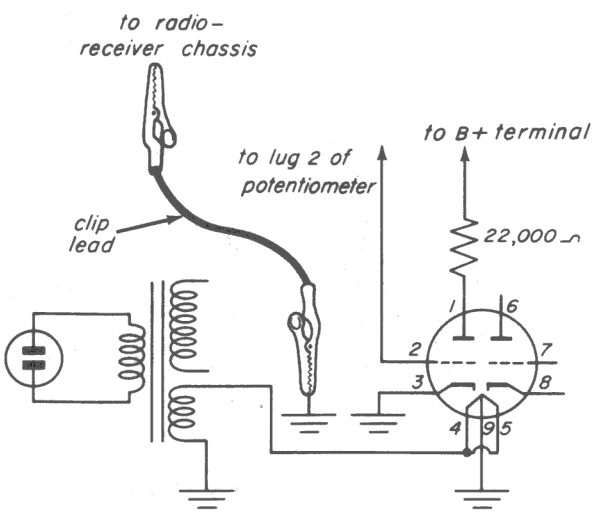


Fig. 19-5

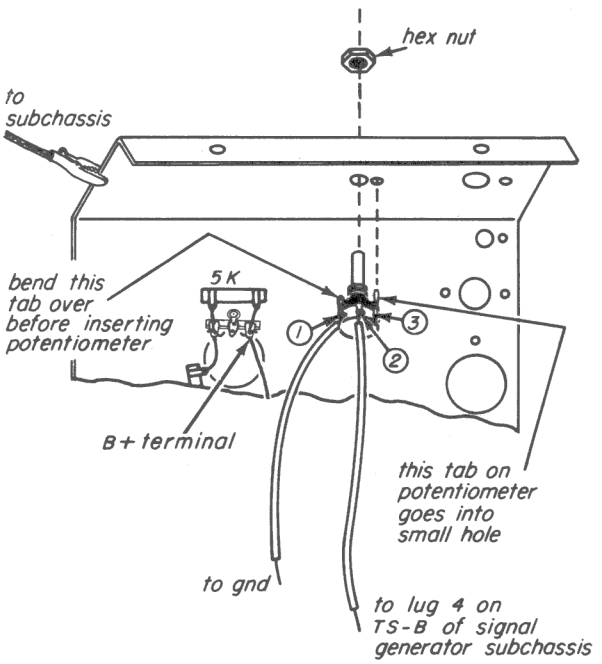


Fig. 19-6

Step 11. Connect one end of a jumper lead (terminated in alligator clips) to the signal-generator subchassis.

Check your complete wiring with the illustrations shown in Fig. 19-4. The portion of the subchassis that you have wired is shown in schematic diagram form in Fig. 19-5.

JOB 19-3

To prepare the radio-receiver chassis for Experiment 19-1.

Procedure.

Step 1. Remove the lead that is connected to the junction of the 5,000- and 10,000-ohm resistors on the radio receiver chassis.

Step 2. Insert a 500,000-ohm potentiometer (with split-knurled shaft) through the hole on the left of the front apron looking from the rear of the chassis, as shown in Fig. 19-6. The terminals should face away from the bottom of the chassis. Secure the potentiometer with a nut finger tight.

Step 3. Make temporary connections and temporary solder joints for all the steps that follow in this experiment. Solder the free

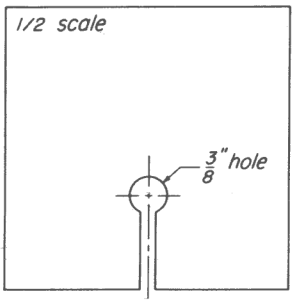


Fig. 19-7

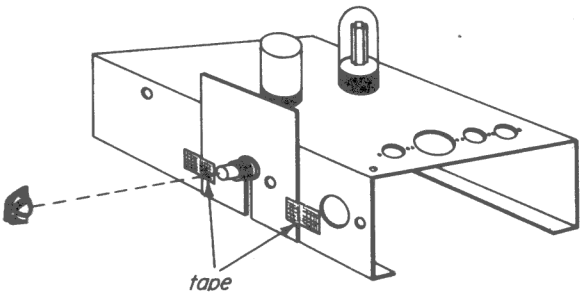


Fig. 19-8

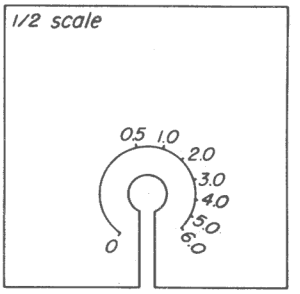


Fig. 19-9

end of the 12-inch lead that is connected to lug 4 of TS-B on the signal generator subchassis to lug 2 (center) of the potentiometer.

Step 4. Connect the signal-generator subchassis and the radio-receiver chassis together with the jumper lead.

Step 5. Connect lug 1 of the potentiometer to a ground lug on the electrolytic capacitor.

JOB 19-4

To prepare a calibrated bias-voltage supply.

Procedure.

Step 1. Obtain a piece of thin white cardboard about 3 x 3 inches (a 3 x 5 index card is very good) and cut it out as shown in Fig. 19-7. If you do not have a compass handy to make the 3/8-inch circle, use a flat washer from one of the chassis connectors that you received in Kit 10. Use the inside hole of the washer to trace out an approximate 3/8-inch hole.

Step 2. Loosen the nut holding down the potentiometer on the receiver chassis, and slip the prepared card under it as shown in Fig. 19-8, passing the slot in the card around the shaft of the control. Line up the edge of the card even with the bottom of the chassis, and secure it in position with a piece of cellulose tape on each side.

Make sure that the terminals of the potentiometer are facing the bent-over flange on the bottom of the chassis before the nut is tightened. Mount the pointer knob that you received in Kit 9 on the control shaft so that it points straight down when the switch is turned off.

Step 3. Using the 6-volt cells that are terminated with alligator clips, connect the negative alligator clip to lug 3 of the potentiometer, and the positive alligator clip to any convenient ground point on the chassis.

Step 4. Set up your multimeter to the 25-VDC range, and connect the negative meter lead to terminal 2 of the potentiometer. Connect the positive meter lead to the chassis. Use your shielded lead with alligator clips for the meter leads.

Caution: Be sure the outside shield is thoroughly insulated and use it as the negative lead.

Step 5. Adjust the potentiometer to give a one-half volt reading on the meter. (Remember that on the 25-volt scale, every two divisions correspond to one volt.) Using a sharp pencil, mark the position of the pointer and label this point –0.5 volt.

Step 6. Adjust the potentiometer for a one-volt reading on the meter. Mark the position of the pointer and label the point as in the previous step. Repeat the operation for –2, –3, –4, –5, and –6 volts. Also mark the zero point at the most counterclockwise position just before the switch is turned off. Your card should be marked similarly to the one shown in Fig. 19-9. You now have a calibrated source of bias voltage from 0 to –6 volts.

Caution: Before going on with the experiment, carefully go over your wiring and compare it with Figs. 19-4, 5, and 6 to make sure that all the wiring instructions have been accurately followed. Check all terminal lugs and tube socket terminals for excess solder that might short terminals next to each

other, or for solder that has dripped down and might short the lug to the chassis.

EXPERIMENT 19-1

To learn how the grid voltage affects the plate current.

Procedure.

Step 1. Insert the 12AU7 tube in its socket in the signal generator sub-chassis. Remember to be especially careful when inserting and removing miniature tubes. Check that the 6X5-GT tube is in its socket.

Step 2. Plug in the line cords of both the receiver and signal-generator subchassis into a-c power outlets. Check to see that both tubes light up. If not, remove the a-c plugs and recheck your wiring. Allow about 30 seconds for the tubes to heat up.

Step 3. Set up the multimeter to operate on the 10-MA DC range. Connect the positive test lead of the meter to the B+ terminal (see Fig. 19-6) of the radio receiver chassis. Connect the negative or common test lead of the meter to terminal lug 1 of TS-B on the signal generator sub-chassis.

Step 4. Using the calibrated potentiometer, set the bias voltage to each of the voltages called for in the table below. Measure the plate current that flows at each bias voltage. Record your readings in Table A.

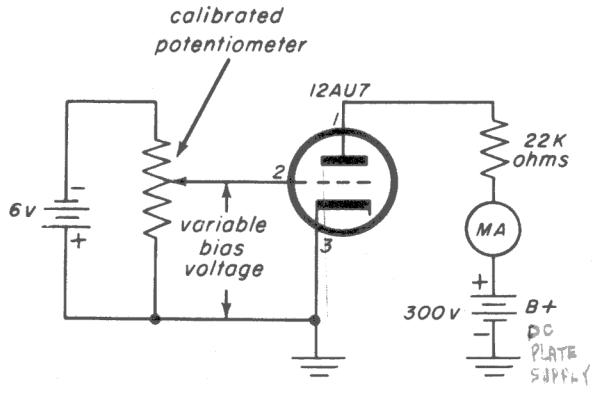


Fig. 19-10

TABLE A

Bias voltage (volts)	Plate current (ma)
0.0	
−0.5	8.3 / 8.52
−1.0	7.9 / 8.12
−2.0	6.9 / 7.3
−3.0	6.2 / 6.2
−4.0	5.8 / 5.7
−5.0	5.4 / 5.6
−6.0	5.2 / 5.3

Step 5. Disconnect both line cords from the a-c outlet.

Discussion. The experimental circuit that you wired for this experiment is shown in Fig. 19-10. It uses one of the two triode sections of the 12AU7 tube. The other triode section is not used. The plate voltage for the tube is obtained from the radio-chassis power supply. A variable grid bias-voltage is obtained from the calibrated 6-volt power supply that you constructed. This is made up of the 6-volt battery using the four series-connected cells with the 500,000-ohm potentiometer connected across the battery as a variable voltage divider. It permits the grid voltage to be varied between zero and −6 volts. The milliameter in series with the plate circuit is used to measure the amount of current flowing from cathode to plate. Typical results are shown in Table B.

In this experiment you can see that the grid voltage controls the plate current, varying it from about 9 milliamperes at zero volts on the grid to about 5.5 milliamperes with about −6 volts on the grid. As the grid is made more negative the plate current is reduced, and as the grid is made more positive, the plate current is increased. It is this control of the plate current of the tube by the grid voltage that makes possible the many uses of the electron tube, as we shall see.

TABLE B	
Bias voltage (volts)	Plate current (ma)
0	8.8
−0.5	8.4
−1.0	8.0
−2.0	7.5
−3.0	6.8
−4.0	6.4
−5.0	6.0
−6.0	5.6

EXPERIMENT 19-2

To study the relationship between the grid voltage and the plate voltage of an electron tube.

Procedure.

Step 1. Disconnect the milliameter from the circuit, and set up the meter for service on the 500-VDC range.

Step 2. Connect together with a piece of hookup wire the two points in the circuit that were previously connected by the meter; that is, connect the B+ terminal on the radio chassis to terminal lug 1 of TS-B on the signal generator subchassis.

Step 3. Insert both line cords into a-c power outlets.

Step 4. Turn the 500,000-ohm control knob to obtain zero grid bias.

Step 5. Touch the positive probe to pin 1 (plate) of the 12AU7 tube socket and the negative probe to pin 3 (cathode) of the tube socket. Record the plate to cathode voltage here:

65 volts d.c.

Step 6. Turn the 500,000-ohm control to obtain −6 volts bias.

Step 7. Touch the positive voltmeter probe to pin 1 (plate) of the 12AU7 tube socket and the negative probe to pin 3 (cathode) of the tube socket. Record the plate to cathode voltage here:

155 volts d.c.

Step 8. Remove both line cords from the a-c power outlets.

Discussion. There are two important observations to make in this experiment. First, note that changing the grid-bias voltage from 0 volts to −6 volts changes the plate to cathode voltage from 60 volts to 160 volts. A six volt change at the grid produces a 100 volt change (160 v. − 60 v.) change in the plate to cathode voltage. Second, note that when the grid voltage is *increased* in the positive direction (less negative) from −6 volts to 0 volts, the plate voltage *decreases* from 160 volts to 60 volts. When the grid voltage is most positive, the plate voltage is least positive, and when the grid voltage is most negative, the plate voltage is most positive. That is, the grid-voltage changes and the plate-voltage changes are *opposite in phase*.

Also, since we know that when the grid voltage is most positive, the plate current is greatest, and at the same time the plate voltage is least positive, we can say that the plate current and plate voltage are opposite in phase.

EXPERIMENT 19-3

To learn that the sum of the plate-to-cathode voltage and the voltage across the 22,000-ohm resistor is always equal to the d-c plate supply (B+) voltage.

Procedure.

Step 1. Insert both line cords into a-c power outlets.

Step 2. Turn the 500,000-ohm potentiometer control knob to obtain zero bias.

Step 3. With the multimeter set up for service on the 500-VDC range, touch the positive probe to pin 1 (plate) and the negative probe to pin 3 (cathode) of the 12AU7 tube socket. Observe the voltage indication and record the voltage in Table C.

Step 4. Touch the positive probe to the lead of the 22,000-ohm resistor that goes to tie lug terminal 1 of TS-B on the signal generator subchassis. Touch the negative probe to the lead of the 22,000-ohm resistor that goes to pin 1 (plate) of the 12AU7 tube socket. Record the voltage indication in Table C.

Step 5. Add together the sum of the voltages measured in Step 3 and 4. Record the sum of the two voltages in Table C.

Step 6. Measure the B+ supply voltage between the B+ terminal on the receiver chassis and ground (positive meter lead to the capacitor terminal; negative meter lead to chassis.) Record the voltage in Table C.

TABLE C — NO BIAS	
Voltage across tube:	65 v
Voltage across resistor:	212 v
Sum:	277 v
Power-supply voltage:	285

Step 7. Turn the knob on the 500,000-ohm potentiometer to obtain −3 volts bias.

Repeat Steps 3, 4, 5 and 6. Record the voltages in Table D.

TABLE D — BIAS OF −3 VOLTS	
Voltage across tube:	130
Voltage across resistor:	152
Sum:	282
Power-supply voltage:	282

Step 8. Disconnect both line cords.

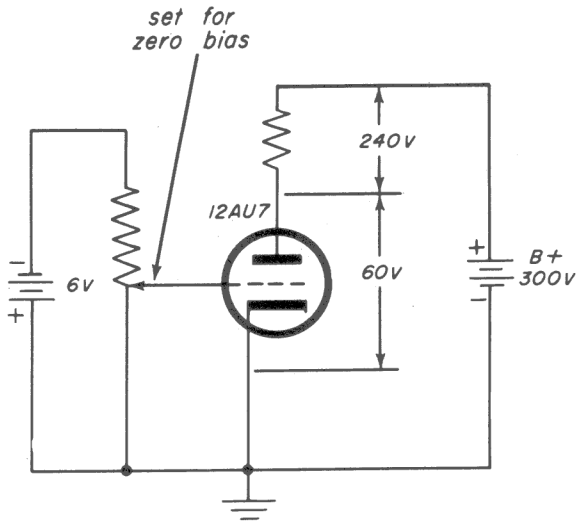


Fig. 19-11

Discussion. The diagram shown in Fig. 19-10 has been redrawn in slightly different form in Fig. 19-11 to help you see more clearly the results of the measurements made. In Step 3 you found that the voltage measured from plate to cathode was about 60 volts. Step 4 showed that the voltage across the 22,000-ohm resistor measured about 240 volts. The plate supply (B+) voltage measured in Step 5 was found to be around 300 volts. Now if you will add the voltage measured in Step 3 (60 volts) to the voltage measurement of Step 4 (240 volts), the total will exactly be equal to the B+ voltage measurement of 300 volts. You can see that the applied 300 volts divides between the resistance of the tube and the series-connected 22,000-ohm resistor. Part of the voltage appears across the tube and the rest across the resistor. The sum of the individual voltage drops in a series circuit is equal to the applied voltage. The tube, resistor, and applied voltage are all connected in series. When the bias on the tube is changed, as in Step 7 of the experiment, the voltages distribute themselves differently, but their sum is still equal to the supply voltage.

EXPERIMENT 19-4

To learn that the plate-to-cathode circuit of an electron tube has a d-c ohmic resistance.

Procedure.

Step 1. In Experiment 19-1, Step 4, you measured the plate currents for various bias voltages and recorded them in Table A. From the table, obtain the plate current when the bias is zero volts. Record that reading again here:

8.5 ma d.c.

Step 2. In Experiment 19-2, Step 5, you measured the plate-to-cathode voltage when the 500,000-ohm potentiometer control knob was adjusted for zero bias. Record that reading again here:

65 volts d.c.

Step 3. Divide the voltage recorded above in Step 2 by the current recorded above in Step 1. Record the resistance here:

1647 ohms

Step 4. From Table *A* in Experiment 19-1 obtain the plate current when the 500,000-ohm control knob was set for −6 volts bias. Record that reading again here:

5.3 ma d.c.

Step 5. In Experiment 19-2 Step 7, you measured the plate to cathode voltage when the 500,000-ohm potentiometer control knob was set for −6 volts bias. Record that reading again here:

155 volts d.c.

Step 6. Divide the voltage recorded above in Step 5 by the current recorded above in Step 4. Record the resistance here:

29,245 ohms

Discussion. In Step 3, when you divide the plate voltage by the plate current (assuming that the voltage is 60 volts and the current is 8.8 ma), you will find the resistance (R_b) to be approximately:

$$r_b = \frac{E_b}{I_b} = \frac{60}{0.0088} = 6{,}800 \text{ ohms}$$

In Step 6 when you divide the plate voltage by the plate current (assuming that the plate voltage is 160 volts and the current is 5.6 ma) you will find the resistance (R_b) to be approximately:

$$r_b = \frac{E_b}{I_b} = \frac{160}{0.0056} = 28{,}500 \text{ ohms}$$

You learned from this experiment that the plate to cathode resistance of the tube was changed from 28,500 ohms when the bias is −6 volts to 6,800 ohms when the grid bias is 0-volts. You can see that an electron tube, unlike a resistor, does not have a constant resistance, but its resistance depends upon the amount of current flowing through it. The resistance of a resistor is practically independent of the current flowing through it (unless it heats up enough to change its temperature). Ordinary resistors are therefore *linear resistances*. Electron tubes, however, are *non-linear resistances*, because their resistance is not constant but depends upon the amount of current flowing through the tube.

Values of plate-to-cathode resistance larger than 30,000 ohms can be obtained by increasing the negative bias to more than the –6 volts used in this experiment. Smaller plate-to-cathode resistance values than 8,000 ohms can be obtained by decreasing the negative bias, making the grid more positive than the 0 bias voltage used in these experiments.

The voltage you measured from plate to cathode was a *d-c* voltage. The current you measured flowing from cathode to plate did not vary and was a *d-c* current. Therefore the plate-to-cathode resistance of the tube that you found in this experiment by dividing a d-c voltage by a d-c current is a *d-c resistance*. In a later experiment, you will find the *a-c resistance* of a tube.

JOB 19-5

To prepare the circuit for Experiment 19-5.

Note: Refer to Figs. 19-4*b* and 19-6, while making the changes.

Procedure.

Step 1. Disconnect the positive and negative battery leads and remove the battery from the circuit.

Step 2. Disconnect two flashlight cells from the string of four dry flashlight cells in series.

Step 3. Remove the negative alligator-clip lead from one group of cells, and solder the alligator-clip lead to the free negative terminal of the other group of cells, to make a 3-volt battery.

Step 4. Disconnect the lead from lug 4 of TS-B to terminal 2 of the potentiometer.

Step 5. Disconnect the lead from terminal 1 of the potentiometer to the radio-receiver chassis.

Step 6. Remove the potentiometer and save it for a later Experiment Lesson.

Step 7. Remove the lead from terminal 1 of TS-B to the B+ terminal on the radio receiver chassis.

Step 8. Set up the meter for service on the 10-ma range, and connect it in place of the lead removed in Step 7 (positive test lead to the B+ terminal and negative test lead to lug 1 of TS-B).

Step 9. Connect the negative alligator clip lead of the 3-volt battery to lug 4 of TS-B.

Step 10. Connect the positive alligator clip lead from the 3-volt battery to any convenient point on the chassis. The circuit you have now wired is shown in Fig. 19-12*a*.

EXPERIMENT 19-5

To study the ways in which bias voltages can be distributed in the grid and cathode circuits of an electron tube.

Procedure.

Step 1. Connect both line cords to a-c power outlets and allow the tubes to warm up.

Step 2. Measure the plate current flowing, and record it here:

6.6 ma d.c.

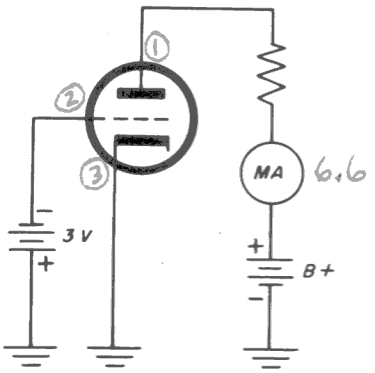
Step 3. Disconnect both line cords from the a-c power outlets.

Step 4. Remove the meter, set it up on the 25-VDC range, and measure the voltage between pins 2 and 3 (grid and cathode) of the 12AU7 tube socket. Record the voltage and the polarity of the grid below:

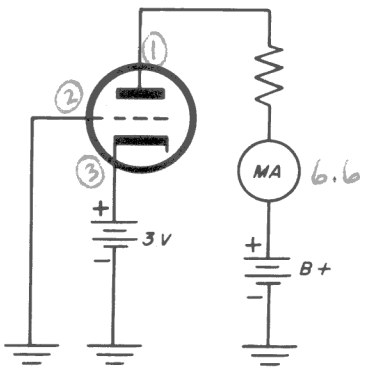
3.2 volts d.c.	— grid polarity

Step 5. Remove the 3-volt battery from the circuit.

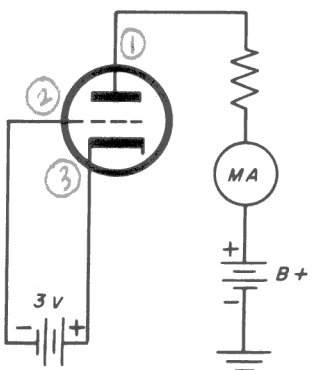
Step 6. Locate the lead from pin 2 of the tube socket to lug 4 of TS-B. Disconnect it at lug 4 of the terminal strip (refer to Fig. 19-4*b*).



(a)



(b)



(c)

Fig. 19-12

Step 7. Locate the lead from pin 3 of the tube socket to lug 2 of TS-B. Disconnect it at lug 2 of the terminal strip.

Step 8. Reverse these two leads; that is, connect the lead from pin 3 of the tube socket to lug 4 of TS-B, and the lead from pin 2 of the tube socket to lug 2 of TS-B.

Step 9. Connect the positive lead of the 3-volt battery to lug 4 of TS-B, and the negative battery lead to any convenient point on the chassis. The circuit you have now wired is shown in Fig. 19-12*b*.

Step 10. Connect both line cords to a-c power outlets, and allow the tubes to warm up.

Step 11. Set up the meter to the 10-ma d-c range, and reconnect the meter with the positive test lead to the B+ terminal and the negative test lead to lug 1 of TS-B.

Step 12. Measure the current flowing, and record your reading here:

6.6 ma d.c.

Step 13. Disconnect both a-c line cords from the power outlets.

Step 14. Remove the meter and set it up to the 25-DC range. Measure the voltage between pins 2 and 3 (grid and cathode) of the 12AU7 tube socket. Record the voltage and note whether the grid is negative or positive here:

3.2 volts d.c.	— polarity

How does the plate current and the grid voltage and polarity compare with that measured in Steps 2 and 4? SAME

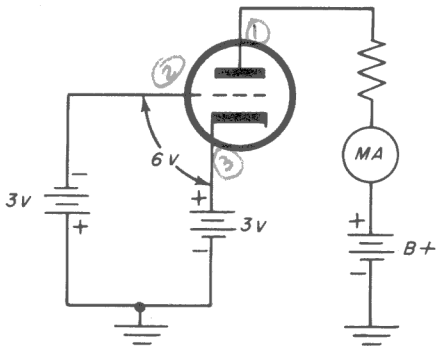


Fig. 19-13

Step 15. Remove the lead that connects pin 2 of the 12AU7 tube socket to lug 2 of TS-B.

Step 16. Solder 6 inch leads to the positive and negative terminals of the remaining 3-volt battery. Solder the negative lead to pin 2 of the 12AU7 tube socket. Be sure to make a temporary connection that you can easily remove. Solder the positive lead to lug 2 of TS-B. The circuit you have now wired is shown in Fig. 19-13.

Step 17. Repeat Steps 10, 11, 12 and 13. Record your reading the plate current here:

5.4 ma d.c.

Step 18. Disconnect both a-c line cords.

Step 19. Remove the meter, set it up to the 25-VDC range. Measure the voltage between pins 2 and 3 (grid and cathode) of the 12AU7 tube socket. Record your reading here:

6 volts d.c.

Note the polarity of the grid with respect to cathode:

— grid polarity

Discussion. This experiment shows that a positive voltage applied to the cathode of an electron tube has the same effect as a negative voltage applied to the grid. In both cases, the voltage between grid and cathode is –3 volts, with the grid negative with respect to the cathode. The current is the same in both cases, since the bias is the same. The circuits used in the experiment are shown in Fig. 19-12*a* and *b*. The two circuits are exactly the same except for the location of the ground point or chassis connection. The grid portion of the two circuits has been redrawn in Fig. 19-12*c*, with the two ground connections replaced by a wire, which clearly shows that circuits *a* and *b* are equivalent as far as the net voltage between grid and cathode is concerned. The difference between the two circuits is that in one case the negative terminal of the battery is grounded. Thus if a –3 volt bias is needed to set the operating point of a tube it can be obtained by connecting either a –3 volt source in the grid circuit or a +3 volt source in the cathode circuit. If there is both a negative voltage in the grid circuit and a positive voltage in the cathode circuit, as in Fig. 19-13, the total voltage across grid and cathode of the tube is the sum of these two voltages, as you have seen in Step 19. These are important points, because many radio and television circuits obtain bias for the tube by a combination of a cathode voltage and a grid voltage. Remember that it is the *net* voltage between grid and cathode that controls the flow of current in an electron tube.

EXPERIMENT 19-6

To learn that grid current does not flow when the grid is negative with respect to the cathode.

Procedure.

Step 1. Disconnect both batteries and remove them from the circuit.

Step 2. Unsolder the lead at lug 4 of TS-B on the signal-generator subchassis (refer to Fig. 19-4*b*). Connect the lead from pin 2 of the 12AU7 tube socket to lug 4 of

TS-B, and the lead from pin 3 of the tube socket to lug 2 of TS-B.

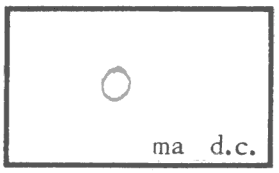
Step 3. Connect a lead from lug 1 of TS-B to the B+ terminal on the radio-receiver chassis.

Step 4. Connect the negative lead of one of the 3 volt batteries to lug 3 of TS-B, and the positive lead to any convenient ground point on the chassis.

Step 5. Insert both line cords into the a-c power outlets. Wait for the tubes to heat.

Step 6. Set the multimeter up for service on the 10-MA DC range.

Step 7. Touch the negative probe to lug 3 of TS-B and touch the positive meter test lead to lug 4 of TS-B. Observe the millimeter indication. Record the current here:



Step 8. Disconnect both line cords

Discussion. In this experiment, you connected the bias voltage between grid and cathode so that the grid was negative with respect to cathode, as shown in Fig. 19-14. The bias voltage was obtained from two series connected cells and placed a 3.0-volt negative bias on the grid. The milliameter indication was zero, as observed in Step 7. This means that the electrons leaving the cathode did not flow to the grid because of a repelling action. An electron is a negative particle and is repelled by the negative potential of the grid. Thus, no grid current flows when the grid is negative.

EXPERIMENT 19-7

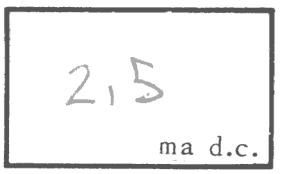
To learn that grid current flows when the grid is made positive with respect to the cathode.

Procedure.

Step 1. Reverse the battery by connecting the negative battery lead to the chassis, and the positive battery lead to lug 3 of TS-B.

Step 2. Insert both line cords into power outlets; allow the tubes to heat.

Step 3. With meter set to the 10-MA DC range, touch the negative meter probe to lug 4 of TS-B and the positive probe to lug 3 of TS-B. Observe the milliameter indication. Record the current here:



Step 4. Disconnect both line cords.

Discussion. In this experiment, you connected the bias voltage between grid and cathode so that the grid was positive with respect to the cathode, as shown in Fig. 19-15. The bias voltage was obtained as before from two cells, but in this case a 3.0-volt positive voltage was placed on the grid. The current recorded in Step 3 was about 4.0 milliamperes. This shows that

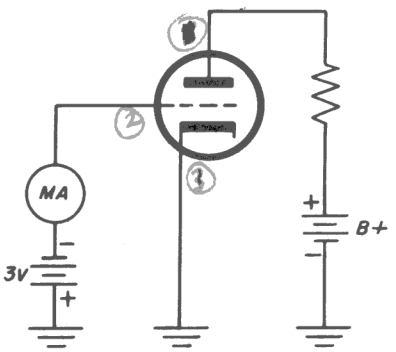


Fig. 19-14

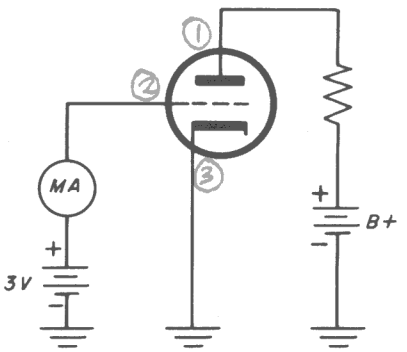


Fig. 19-15

electrons leaving the cathode were attracted to the positive grid. An electron is a negative particle and will move to a positively charged grid, resulting in grid current flow. Most amplifier circuits are arranged so that the grid is negative with respect to the cathode at all times. If the grid becomes positive, either due to excessive signal or a leaky coupling capacitor, distortion usually results.

EXPERIMENT 19-8.

To observe the amplifying effect of an electronic tube.

Procedure.

Step 1. Remove the 3-volt battery from the circuit and reconnect all your flashlight cells in series to make a 6-volt battery, with alligator leads attached.

Step 2. Unsolder the lead at lug 2 of TS-B (refer to Fig. 19-4*b*). Connect this lead from pin 3 of the tube socket to lug 3 of TS-B.

Step 3. Connect (temporarily) a lead from pin 4 of the 12AU7 tube socket on the signal-generator subchassis to lug 4 of TS-B.

Step 4. Connect the positive lead of the 6-volt battery to lug 3 of TS-B, and the negative lead to any convenient point on the chassis.

Step 5. Insert both line plugs into a-c power outlets.

Step 6. Set up the multimeter for service on the 75-VAC range. Insert the positive lead into the OUTPUT jack. Touch one probe to pin 2 (grid) of the 12AU7 tube socket and the other probe to the chassis. Observe the voltage reading and record it here:

6.0 volts a.c.

The voltage you measure will be less than 6.3 volts because of the series capacitor in the output meter circuit.

Step 7. Touch one probe of the meter to pin 1 (plate) of the 12AU7 tube socket and the other probe to the chassis. Observe the voltage reading and record it here:

74 volts a.c.

Step 8. Divide the voltage measured in Step 7, which is the output-signal voltage, by the voltage measured in Step 6, which is the input-signal voltage. The result is the voltage gain. Do your calculation here:

$$\frac{\text{a-c output voltage}}{\text{a-c input voltage}} = \frac{74 \text{ volts}}{6 \text{ volts}}$$

12.3 = voltage gain

Discussion. The experimental circuit is shown in Fig. 19-16. The 12AU7 electron tube is connected as a voltage amplifier. Bias voltage between the grid and cathode is obtained from the 6-volt battery, the grid being negative with respect to cathode. The 6.3-volt heater winding supplies an a-c signal voltage having an amplitude of about five volts as measured in Step 6. The meter is used as an output meter to keep out the d-c plate voltage. The a-c plate voltage measured in Step 7 about 70 volts. This means that the tube has helped amplify the 5-volt signal about 14 times or:

$$\text{voltage gain} = \frac{70}{5} = 14 \text{ times}$$

This illustrates one of the most important properties of an electron tube — its ability to amplify.

In a later lesson you will learn more about how an amplifier circuit works. You will also learn how to obtain still greater gain or amplification using the 12AU7 and other electron tubes.

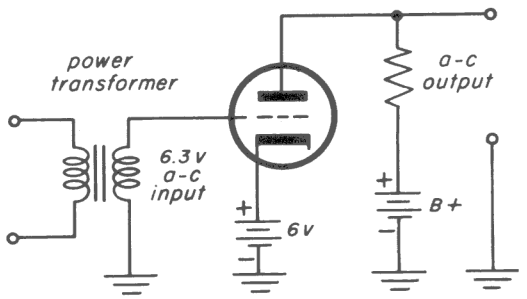


Fig. 19-16

JOB 19-5

To prepare the signal-generator chassis for Experiment Lesson 20.

Procedure.

Step 1. Unsolder and remove the 22,000-ohm resistor that connects between pin 1 of the tube socket to lug 1 of TS-B. Remove the lead from this lug to the B+ terminal on the radio chassis.

Step 2. Unsolder and remove the lead that connects from pin 3 of the tube socket to lug 3 of TS-B.

Step 3. Unsolder and remove the lead that connects from pin 4 of the tube socket to lug 4 of TS-B.

Step 4. Unsolder and remove the lead that connects pin 2 of the tube socket to lug 4 of TS-B.

Step 5. Disconnect the 6-volt battery from the signal-generator chassis.